Effect of Chlorhexidine Mouth Wash and Fluoridated Mouth Wash on Mechanical Properties of Orthodontic Arch Wires (An in vitro Study)

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ABSTRACT

Aims: The aims of the this study were to measure the effect of chlorhexidine and fluoridated mouth wash on mechanical properties of stainless steel and nickel titanium wires and to study the effect of three time intervals (3, 7, and 10 days) immersion on these mechanical properties. **Materials and Methods:** Two types of orthodontic wires were taken which included stainless steel and superelastic nickel titanium wires (Dentaurum, Germany). The 0.016×0.016 inch wires were selected. Each type of wires divided into seven groups; control group and six experimental groups in which the wires immersed in the chlorhexidine and fluoridated mouth wash for 3, 7, and 10 days and then the mechanical properties of wires (yield stress, ultimate tensile stress, modulus of elasticity) measured by using the universal tensile testing machine. **Results:** The results of the present study showed that a significant difference in the mechanical properties of both stainless steel and nickel titanium wires between the control group and experimental groups immersed in the fluoridated mouth wash and this decreased in the mechanical properties as immersion time increased. Also the results of the present study showed that a non significant difference in the mechanical properties of both stainless steel and nickel titanium wires between the control group and experimental groups immersed in the chlorhexidine mouth wash. **Conclusions:** The results of the present study indicated that the fluoridated mouth wash decreased the mechanical properties of stainless steel and nickel titanium wires and this degradation in mechanical properties could contributed to prolong orthodontic treatment. While the chlorhexidine has no effect on mechanical properties of stainless steel and nickel titanium wires.

Key words: Orthodontic wires, chlorhexidine, fluoride.

Intra–orally placed materials (i.e., wires, brackets) exhibit a pattern of continuous reaction with the environmental factors present in the open oral cavity.(1) These environmental conditions of the oral cavity might alter the morphological, structural and compositional characteristics, force delivery of arch wires, superelasticity and fracture of orthodontic alloy.(2) These oral environments include saliva, acids arising from degradation and decomposition of food (pH), oral flora and its by products, temperature change and stress.(3–5)

One of the most important components of successful orthodontic treatment is the maintenance of good oral hygiene and caries control, fluoride–containing commercial mouth washes, toothpastes, and prophylactic gels are generally used to avoid dental caries or to reduce dental sensitivity. Fluoride prophylactic agents, such as acidulated phosphate fluorides, have been used extensively to prevent demineralization or remineralization of white spot lesion around orthodontic brackets.(6, 7) However, the fluoride ions in the prophylactic agents have been reported to cause corrosion and discoloration of orthodontic wires.(8–10) The detrimental effect of fluoride ions on the corrosion resistance of titanium or titanium alloys has been extensively reported. Fluoride ions are very aggressive on the protective TiO_2 film formed on titanium and titanium alloys. Since outermost surface of nickel titanium arch wire contains mainly TiO_2 film with trace amount of NiO, fluoride enhanced corrosion of the nickel titanium arch wires in fluoride containing environment has been considered.(11, 12) Fluoride–containing environments can penetrate into the narrow crevices between the orthodontic arch wire and bracket in the mouth which is not cleaned out thoroughly. Topical high fluoride concentrations will stay in place and attack the arch wire/bracket interface depending on the fluoride concentration. This may increase friction force between arch wire and bracket. Using topical fluoride agents with nickel titanium wire could decrease the functional unloading mechanical properties of wires and contribute to prolonged orthodontic treatment.(13, 14) The deterioration of the corrosion resistance of orthodontic wires has two consequences; the first is a loss of the physical properties which play in the success of the clinical treatment, the second is the released of nickel ions, which have been shown to be toxic and the cause of allergic reaction.(15, 16)

The aims of the this study were to measure the effect of chlorhexidine and fluoridated mouth wash on mechanical properties of stainless steel and nickel titanium wires and to study the effect of three time intervals (3, 7, and 10 days) immersion on these mechanical properties.

MATERIALS AND METHODS

Two types of orthodontic wires were taken which include spring hard stainless steel and superelastic nickel titanium wires (Dentaurum, Germany). The 0.016×0.016 inch wires were selected. Each type of wires divided in to seven groups: 1– Control group in which the wires in dry condition. 2– Group A in which the wires immersed in fluoride solution (Biofresh–F mouth wash) the active ingredients of it: Sodium monofluorophosphate 0.137%, sodium fluoride 0.0133% and excipients, made in SAR, for 3 days. 3– Group B in which the wires immersed in fluoride solution for 7 days. 4– Group C in which the wires immersed in fluoride solution for 10 days. 5–Group D in which the wires immersed in chlorhexidine solution (Biofresh–K mouth wash) the active ingredients of it: 0.12% chlorhexidine gluconate and excipients, made in SAR, for 3 days. 6– Group E in which the wires immersed in chlorhexidine solution for 7 days. 7– Group F in which the wires immersed in chlorhexidine solution for 10 days. For each group, 10 wires prepared and put in a glass container and 200 ml of solution (fluoride or chlorhexidine) added and then covered perfectly and incubated at 37^o in the incubator for 3, 7, and 10 days.

Testing the Samples:

The samples test by using the universal tensile testing machine (Zweigle) models 73, made in Belgium (Figure 1). The speed of the machine controlled as 5 mm/sec. The testing procedure include the following steps:

1– The length of the wire was measured as 20 mm as stander for all sample. 2– Choice the load range between 0–50 Kg. 3– Clamp the sample through the jaws of the machine. 4– Adjusted the machine by making zero balance of control unit, then switch on the machine, when the specimen is under tension, load increased by a suitable increment. 5– Record the result of applied load in Kg versus elongation produced. 6– The test will continue until breaking of the specimen occur (Figure 2). 7– Switch of the machine. 8– Transfer the load from Kg to Newton (N) by N= Kg×10. 9– Calculate the cross section area of the wire by multiply the length and height .10– Transfer the stress in MPa by stress= (load in N)/(surface area of the specimen). 11– From the above data plot the stress–strain curve (Figure 3). 12– From the curve we can obtain the following:

a– Calculate the yield stress by drawing a line from 0.2 of the gauge length of the specimen parallel to the curve line, the inter section point represent the yield point (0.2 offset yield stress). b– The highest point in the stress–strain curve represent the ultimate tensile stress. c– Calculate the modulus of elasticity which represent tan Ø= stress/strain. This procedure described by Sarmad.[17]

Figure (1): Device used in the tensile strength test.

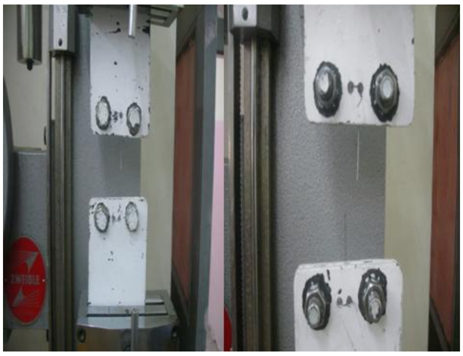

Figure (2): Before and after tensile test.

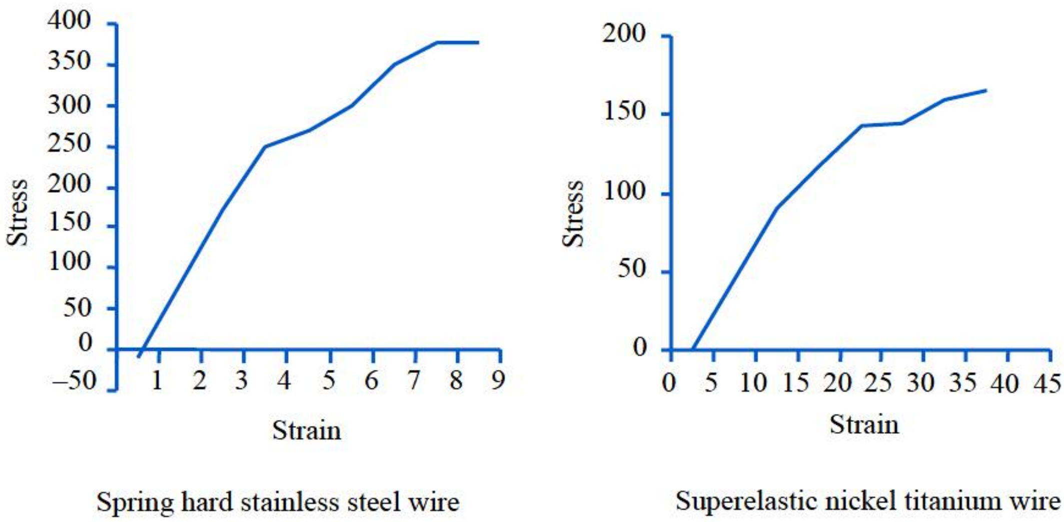

Figure (3): Stress strain curve.

RESULLTS

Spring Hard Stainless Steel Arch Wires:

The minimum, maximum, mean values, standard error and standard deviation of the three tensile properties of the seventh groups of the spring hard stainless steel arch wire are given in Table (1). It can be noticed that the highest mean of the yield stress, ultimate tensile stress and modulus of elasticity are for the first (control) group, while the 10 days fluoride groups shows the minimum mean and the remaining groups are distributed between the higher and lower level. The Analysis of Variance (ANOVA) for the three tensile properties of the seventh groups showed significant differences ($p \leq 0.01$) among them as illustrated in Table (2) .The result of Duncan Multiple Analysis Test (Table 3) showed significant differences at $p \leq 0.05$ when the first group (control group) compared with groups immersed in fluoride (3, 7, and 10 days groups). While there is no significant differences at $p \leq 0.05$ when control group compared with groups immersed in chlorhexidine (3, 7, and 10 days group). Also the results revealed significant differences at $p \leq 0.05$ between groups immersed in fluoride in the yield stress, ultimate tensile stress and modulus of elasticity. While there is no significant differences at $p \leq 0.05$ between groups immersed in chlorhexidine.

Table (1): Descriptive statistics of three tensile properties of the 7 groups of the spring hard stainless steel arch wires.

Property	Groups	No.	Minimum	Maximum	Mean	$\pm$ SD	SE of Mean
Yield Stress (MPa) $\times 10^3$	Control	10	1553	1560	1557.01	2.389	0.7556
	3 Day Fluoride	10	1485.05	1495	1490.24	3.128	0.9892
	7 Day Fluoride	10	1410.99	1412.45	1411.66	0.4354	0.1376
	10 Day Fluoride	10	1328.05	1329.35	1328.62	0.4255	0.1345
	3 Day Chlorhexidine	10	1556.05	1558.01	1556.92	0.4865	0.1538
	7 Day Chlorhexidine	10	1556.06	1557.02	1556.55	0.4166	0.1317
	10 Day Chlorhexidine	10	1556.04	1557	1556.64	0.3275	0.1035
Ultimate Tensile Stress (MPa) $\times 10^3$	Control	10	2177	2183.84	2181.44	2.137	0.6758
	3 Day Fluoride	10	1940	2180.45	1966.42	75.270	23.802
	7 Day Fluoride	10	1890.98	1894.01	1893.04	0.8582	0.2714
	10 Day Fluoride	10	1864.06	1865	1864.70	0.2641	0.0835
	3 Day Chlorhexidine	10	2180.01	2182.05	2181.02	0.7590	0.2400
	7 Day Chlorhexidine	10	2180.73	2182.05	2181.29	0.5259	0.1663
	10 Day Chlorhexidine	10	2180.65	2181.05	2181.05	0.4584	0.1449
Modulus of Elasticity (MPa) $\times 10^2$	Control	10	216.4	221	218.53	1.559	0.4930
	3 Day Fluoride	10	207.07	209.80	208.76	0.6915	0.2187
	7 Day Fluoride	10	199.30	200.40	199.76	0.3358	0.1062
	10 Day Fluoride	10	194.09	194.90	194.71	0.2528	0.0799
	3 Day Chlorhexidine	10	216.40	219.30	218.01	1.219	0.3857
	7 Day Chlorhexidine	10	215.05	219.75	218.06	1.564	0.4946
	10 Day Chlorhexidine	10	215.05	219.75	218.20	1.612	0.5100

Table (2): ANOVA for the three properties of the 7 groups of the spring hard stainless steel arch wires.

Property	SOV	SS	df	MS	F–value	*p*–value
Yield Stress (MPa) ×10^3	Between Groups	499089.67	6	83181.612	35535.146	0.000*
	Within Groups	147.472	63	2.341		
	Total	499237.14	69			
Ultimate Tensile Stress (MPa)×10^3	Between Groups	1334137.1	6	222356.18	274.414	0.000*
	Within Groups	51048.472	63	810.293		
	Total	1585185.6	69			
Modulus of Elasticity (MPa)×10^2	Between Groups	6040.550	6	1006.758	732.424	0.000*
	Within Groups	86.597	63	1.375		
	Total	6127.147	69			

SOV: Source of variance; SS: Sum of Squares; MS: Mean square; df: Degree of freedom.
*Significant difference existed at $p \leq 0.01$

Table (3): Duncan's test for the three properties of the 7 groups of the spring hard stainless steel arch wires.

Property	Groups	No.	Mean	Duncan Groups*
Yield Stress (MPa)×10^3	Control	10	1557.01	A
	3 Day Fluoride	10	1490.24	B
	7 Day Fluoride	10	1411.66	C
	10 Day Fluoride	10	1328.62	D
	3 Day Chlorhexidine	10	1556.92	A
	7 Day Chlorhexidine	10	1556.55	A
	10 Day Chlorhexidine	10	1556.64	A
Ultimate Tensile Stress (MPa)×10^3	Control	10	2181.44	A
	3 Day Fluoride	10	1966.42	B
	7 Day Fluoride	10	1893.04	C
	10 Day Fluoride	10	1864.70	D
	3 Day Chlorhexidine	10	2181.02	A
	7 Day Chlorhexidine	10	2181.29	A
	10 Day Chlorhexidine	10	2181.05	A
Modulus of Elasticity (MPa)×10^2	Control	10	218.53	A
	3 Day Fluoride	10	208.76	B
	7 Day Fluoride	10	199.76	C
	10 Day Fluoride	10	194.71	D
	3 Day Chlorhexidine	10	218.01	A
	7 Day Chlorhexidine	10	218.06	A
	10 Day Chlorhexidine	10	218.20	A

* Different letters mean significant difference existed at $p \leq 0.05$.

Superelastic Nickel Titanium Arch Wires:

The minimum, maximum, mean values, standard error and standard deviation of the three tensile properties of the seventh groups of the nickel titanium arch wire are given in Table (4). It can be noticed that the highest mean of the yield stress, ultimate tensile stress and modulus of elasticity is for the first (control) group, while the 10 day fluoride groups shows the minimum mean and the remaining groups are distributed between the higher and lower level. The ANOVA for the three tensile properties of the seventh groups showed significant differences ($p \leq 0.01$) among them as illustrated in Table (5). The result of Duncan Multiple Analysis Test (Table 6) showed significant differences at $p \leq 0.05$ when the first group (control group) compared with groups immersed in fluoride. Also the result showed significant differences at $p \leq 0.05$ when the first group (control group) compared with groups immersed in chlorhexidine. While there is no significant differences at $p \leq 0.05$ when control group compared with groups immersed in chlorhexidine (3, 7, and 10 days groups) in the yield stress property. Also the results revealed significant differences at $p \leq 0.05$ between groups immersed in fluoride in the three tensile properties, while there is no significant differences at $p \leq 0.05$ between groups immersed in chlorhexidine.

Table (4): Descriptive statistics of three tensile properties of the 7 groups of the superelastic nickel titanium arch wires.

Property	Groups	No.	Minimum	Maximum	Mean	± SD	SE of Mean
Yield Stress (MPa) ×10^3	Control	10	1065.76	1068	1066.97	0.8141	0.2574
	3 Day Fluoride	10	1033.75	1035.70	1034.24	0.6946	0.2196
	7 Day Fluoride	10	985.75	987.05	986.40	0.4317	0.1365
	10 Day Fluoride	10	938	939.02	938.25	0.4981	0.1575
	3 Day Chlorhexidine	10	1066.5	1067.02	1066.84	0.1900	0.0601
	7 Day Chlorhexidine	10	1066.5	1067.05	1066.85	0.1897	0.0600
	10 Day Chlorhexidine	10	1066	1067.05	1066.58	0.3503	0.1107
Ultimate Tensile Stress (MPa) ×10^3	Control	10	1479.5	1480	1479.63	0.1665	0.0526
	3 Day Fluoride	10	1423.05	1425.05	1423.96	0.6174	0.1952
	7 Day Fluoride	10	1273.75	1274.7	1273.99	0.2576	0.0814
	10 Day Fluoride	10	1236.06	1237.5	1236.66	0.4077	0.1289
	3 Day Chlorhexidine	10	1478.78	1479.7	1479.19	0.3528	0.1115
	7 Day Chlorhexidine	10	1478.75	1479.75	1479.16	0.3753	0.1187
	10 Day Chlorhexidine	10	1478.75	1479.95	1479.21	0.4089	0.1293
Modulus of Elasticity (MPa) ×10^2	Control	10	122.75	123.95	123.17	0.4331	0.1369
	3 Day Fluoride	10	120.5	121.01	120.75	0.1458	0.0461
	7 Day Fluoride	10	115.35	116.02	115.82	0.2054	0.0649
	10 Day Fluoride	10	109.7	110.08	109.88	0.1232	0.0389
	3 Day Chlorhexidine	10	122.83	123.05	122.88	0.0754	0.0238
	7 Day Chlorhexidine	10	122.73	123.05	122.87	0.0865	0.0273
	10 Day Chlorhexidine	10	122.75	123.05	122.86	0.0831	0.0262

Table (5): ANOVA for the three properties of the 7 groups of the superelastic nickel titanium arch wires.

Property	SOV	SS	Df	MS	F–value	*p*–value
Yield Stress (MPa) ×10^3	Between Groups	156692.37	6	26115.395	103011.63	0.000*
	Within Groups	15.972	63	0.254		
	Total	156708.34	69			
Ultimate Tensile Stress (MPa)×10^3	Between Groups	679021.60	6	113170.267	737430.52	0.000*
	Within Groups	9.668	63	0.153		
	Total	679031,27	69			
Modulus of Elasticity (MPa)×10^2	Between Groups	1547.480	6	257.913	6304.517	0.000*
	Within Groups	2.577	63	0.041		
	Total	1550.057	69			

SOV: Source of variance; SS: Sum of Squares; MS: Mean square; df: Degree of freedom.
*Significant difference existed at $p \leq 0.01$.

Table (6): Duncan's test for the three properties of the 7 groups of the superelastic nickel titanium arch wires.

Property	Groups	No.	Mean	Duncan Groups*
Yield Stress (MPa)×10^3	Control	10	1066.97	A
	3 Day Fluoride	10	1034.24	B
	7 Day Fluoride	10	986.40	C
	10 Day Fluoride	10	938.25	D
	3 Day Chlorhexidine	10	1066.84	A
	7 Day Chlorhexidine	10	1066.85	A
	10 Day Chlorhexidine	10	1066.58	A
Ultimate Tensile Stress (MPa)×10^3	Control	10	1479.63	A
	3 Day Fluoride	10	1423.96	B
	7 Day Fluoride	10	1273.99	C
	10 Day Fluoride	10	1236.66	D
	3 Day Chlorhexidine	10	1479.19	E
	7 Day Chlorhexidine	10	1479.16	E
	10 Day Chlorhexidine	10	1479.21	E
Modulus of Elasticity (MPa)×10^2	Control	10	123.17	A
	3 Day Fluoride	10	120.75	B
	7 Day Fluoride	10	115.82	C
	10 Day Fluoride	10	109.88	D
	3 Day Chlorhexidine	10	122.88	E
	7 Day Chlorhexidine	10	122.87	E
	10 Day Chlorhexidine	10	122.86	E

* Different letters mean significant difference existed at $p \leq 0.05$.

DISCUSSION

The result of the present study showed a significant difference in the mechanical properties of stainless steel orthodontic wires among control group and experimental groups immersed in fluoridated mouth wash and these result due to the effect of fluoride ions in increasing the corrosion of stainless steel and lead to degradation of mechanical properties and this result in agreement with Walker *et al*.,[18] who found that using topical fluoride agents with beta titanium and stainless steel wire could decrease the functional unloading mechanical properties of the wires and potentially contribute to prolonged orthodontic treatment. A similar result obtained by Kaneko *et al*.,[19] as already indicated that the stainless steel orthodontic wires have been previously shown to be susceptible to corrosion in experimental fluoride solutions. Stress corrosion cracking of stainless steel in the presence of fluoride has also been reported by Shibata *et al*.,[20] although the acidic pH of fluoride agents is considered an important factor in the breakdown of the titanium–based alloy protective oxide layers leading to fluoride–related corrosion and hydrogen embrittlement this result obtained by Nakagawa *et al*.[21] Also, the result of the present study showed a significant difference in the mechanical properties between the three time intervals of immersion in fluoridated mouth wash. This is due to increase corrosion with time and this result is similar to result obtained by Kwon *et al*.,[22] who found that tensile strength and element release were affected by acidic fluoride solution. In particular, sodium fluoride concentration, pH value, and the period of immersion were the factors affecting these properties. Ogawa *et al*.[23] previously reported that there is a linear increase in hydrogen absorption and potential alloy mechanical property degradation with increased fluoride exposure time.

The result of the present study showed a non significant difference in the mechanical properties of stainless steel orthodontic wires among control group and experimental groups immersed in chlorhexidine mouth wash and these results due to that the chlorhexidine has no effect on the protective oxide layers so no corrosion occur and this result in agreement with Sultan,[24] who found that there is no increased in the number and depth of corrosion pits of stainless steel orthodontic wires when immersed on chlorhexidine solution for 1, 7, and 28 days.

The result of the present study showed a significant difference in the mechanical properties of nickel titanium orthodontic wires among control group and experimental groups immersed in fluoridated mouth wash and these results due to the interaction between the fluoride ions and titanium which caused changes to the protective passive layer of the metal. When titanium based orthodontic wires are exposed to fluoride agent, it suggested that hydrofluoric acid is produced and dissolve the protective oxide layers on the surface of titanium alloys; the degradation and loss of the oxide film exposed underlying alloy, leading to corrosion and the absorption of hydrogen ions from aqueous solution, however hydrogen embrittlement and increased fracture susceptibility of titanium orthodontic wires and this result in agreement with Walker *et al*.,[25] and Ramalingam *et al*.[26] They found that after exposure to prophylactic fluoride gels, there was a significant decrease of nickel titanium mechanical properties. Also, similar result obtained by Watanabe and Watanabe.[27] In this result titanium based alloy change color and surface morphology after 1 and 24 hours. Yokoyama *et al*.[28] showed in view of the galvanic current in the mouth, the fracture of the nickel titanium alloys might be attributed to the degradation of the mechanical properties due to hydrogen absorption. Schiff *et al*.[16, 29] showed that the fluoride ions could cause the breakdown of the protective passivation layer that normally exists on the titanium and its alloys, leading to pit corrosion. Also, Lee *et al*.[30] found that the arch wire manufacturer and sodium fluoride concentration had a statistically significant influence on the corrosion resistance, in terms of polarization resistance, of the four different kinds of commercial nickel titanium orthodontic arch wires in acidic fluoride–containing artificial saliva. Another research by Kwon *et al*.,[31] showed that after a 3–days immersion, the amount of the released titanium and molybdenum has much increased for higher sodium fluoride concentration and lower pH value. During the long–period orthodontic treatment, both patient and clinical doctor should carefully use the fluoride–containing products to minimize unexpected damage on orthodontic wires. Huang[32] showed that there is a variation in the surface topography of the nickel titanium orthodontic arch wires in the commercial fluoride–containing environment. The result of the present study disagree with the research obtain by Kwon *et al*.,[33] who found that the wires did not show any visible modification in surface morphology when wires in contact with the fluoride regardless of the pH value of test solution. Also, Fragou and Eliades[34] showed available evidence on intraorally fractured nickel titanium arch wires did not support the implication of hydrogen embrittlement as a failure mechanism. Rather, fractures were found to be related to: (1) Mechanical factors associated with loading of the wire in specific arch sites; and (2) The masticatory forces. Also, the result of the present study showed a significant difference in the mechanical properties between the three time intervals of immersion in fluoridated mouth wash and this due to increase corrosion with time. This result is similar to result obtained by Ogawa *et al*.[23] previously reported that there is a linear increase in hydrogen absorption and potential alloy mechanical property degradation with increased fluoride exposure time.

The result of the present study showed a non significant difference in the mechanical properties of nickel titanium orthodontic wires among control group and experimental groups immersed in chlorhexidine mouth wash and these result due to the chlorhexidine has no effect on the protective oxide layers so no corrosion occur and this result in agreement with Sultan,[24] who found that there is no increased in the number and depth of corrosion pits of stainless steel orthodontic wires when immersed on chlorhexidine solution for 1, 7, and 28 days.

CONCLUSIONS

The results of the present study indicated that the fluoridated mouth wash decreased the mechanical properties of stainless steel and nickel titanium wires and this degradation in mechanical properties could be contributed to prolong orthodontic treatment, while the chlorhexidine has no effect on mechanical properties of stainless steel and nickel titanium wires.

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